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DEMAND AND CONTROL

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"Money: Demand and Control"

...deviations of money from its short-run path, caused by permanent disturbances to the money and reserve markets, could be offset in a shorter period of time with relatively small increases in interest rate volatility.

...The empirical results in this paper do not support the conventional specification of short-run dynamics, in which observed money accommodates itself gradually to changes in money demand. Uniformly superior results were obtained from equations in which money demand adjusts (through changes in the price level) in response to independent changes in the supply of money.

Money: Demand And Control

A better understanding of the public's demand for money is important because of the impact of money on output and prices and the central role assumptions about money demand play in the making of monetary policy. The two articles in this *Review* shed light on the inter-relationship of money demand and strategies to control the money supply. In the first article, John Judd describes and assesses the Federal Reserve's existing strategy for short-run control of the monetary aggregates. In the second article, John Judd and John Scadding establish that independent changes in the money supply, such as those that result from monetary control policies, affect the behavior of money demand.

John Judd, in his article notes that, through the middle of 1982, monetary control had improved on an annual basis but monetary aggregates had become more volatile on a shorter term since the Federal Reserve changed the way it controlled money (from establishing targets for short-term interest rates to focusing on targets for bank reserves.) The article was written prior to the major deregulation of deposit interest rates at the end of 1982. It abstracts from issues concerning monetary variables targeted and annual numerical ranges for monetary aggregates raised by this development to discuss approaches to achieving whatever monetary targets the Federal Reserve chooses.

The Federal Open Market Committee, which sets target ranges for the growth rate of the monetary aggregates, has followed a strategy whereby it attempts to return monetary aggregates to the target range gradually. According to Judd, a major rationale for this practice is that much of the volatility is believed to be self-correcting. Attempts to reduce such variations can add unnecessarily to interest rate fluctuation in the short-run.

Judd warns, however, that there are money supply deviations caused by persistent disturbances to the economy that, if left unchecked, have adverse effects on prices and GNP. Moreover, he argues that "a larger number of unnecessary reactions (on the part of the Federal Reserve) might be less costly to the economy than a smaller number of large persistent monetary control errors."

Judd focuses on the size of changes in nonborrowed reserves initiated by the Fed as a measure of the aggressiveness of monetary control actions. He uses the Money Market model developed at the San Francisco Federal Reserve Bank to estimate the size of changes in short-term interest rates needed for various rates of M1 re-entry into the annual target ranges.

A key element of the model is a provision for the effect of bank loans on the money supply. Most conventional models do not incorporate this relationship.

Using the San Francisco Money Market model, Judd finds that, once the effects of a change in nonborrowed reserves on both open market interest rates and bank lending are accounted for, "given changes in M1 can be accomplished with smaller changes in interest rates." Thus, the costs, as measured by increased interest rate volatility, of closer control of M1 are lower than conventional models would suggest.

He concludes that "a more aggressive approach (to returning monetary aggregates to target) would reduce the incidence of persistent deviations that have significant effects on GNP and prices. Such an approach would also reduce the risk that the Fed would have to resort to inducing persistent swings in short-term interest rates to eliminate large money deviations. Finally, a more aggressive approach might contribute to the stability of long-term interest rates, which are especially important for the performance of the economy."

Judd and Scadding, in their article, test alternative specifications of short-run money demand dynamics to find the one which best predicts the level of real money balances. The two authors note that the conventional specification "went seriously off track'' when it tried to predict the shift in money demand from 1974 to 1976, leading some observers to question whether this was due to the conventional assumption ''that the money supply is endogenous, adjusting to exogenous changes in income and interest rates operating through the demand for money.''

Judd and Scadding question whether the conventional assumption is appropriate for situations in which shocks occur in the supply of money rather than the demand for money.

They believe that the correct specification of the short-run dynamic adjustment in the money demand function ''depends critically on which variables are made exogenous and which endogenous.'' They, therefore, study nine specifications of money demand with different adjusting and exogenous variables. The nine can, however, be grouped into two major categories. The first includes the conventional specification and its variants, in which the quantity of money adjusts with a lag to changes in the demand for money. Specifications in the second group share the feature that money demand adjusts with a lag to changes in the supply of money. The specifications differ among themselves as to which argument of the money demand function bears the burden of adjustment—interest rates, income, prices, or, in one case, a combination of these.

All the equations were put into the same canonical form and estimated with real money balances as the dependent variable. The sample data used in the estimation spanned the period from the first quarter of 1959 to the second quarter of 1974. The equations that yielded reasonable estimation results were then used to simulate money dynamics in the period from the third quarter of 1974 to the third quarter of 1980.

Judd and Scadding found that ''money demand equations in which prices adjust to exogenous changes in money, interest and income outperform equations in which money is the adjusting variable. Equations in which money is the adjusting variable, in turn, outperform equations where interest rates and income are the adjusting variables.''

An Examination of the Federal Reserve's Strategy for Controlling the Monetary Aggregates

John P. Judd*

I. Introduction

On October 6, 1979, the Federal Reserve changed the way it controlled money from establishing targets for short-term interest rates to focusing on targets for bank reserves. The new procedure was expected to result in more interest rate volatility as the rates were freed to respond to market forces. The procedure was also intended to achieve better control of the monetary aggregates. Since October 1979, interest rate volatility has increased, and monetary control has improved on an annual basis. But surprisingly, the monetary aggregates became *more* volatile on a short-term basis.

In February, 1981, the Federal Reserve published results of a System study evaluating the experience under the new control procedure.[1] The study concluded that the increased volatility of the monetary aggregates in 1980 was caused, in part, by unusually large shocks to the money and credit markets. The largest of these shocks came from the Special Credit Control Program implemented in the Spring of 1980. A second conclusion was that more accurate short-run control might have been achieved by more aggressive adjustments in the reserves targets when the quantity of money departed from target.[2] However, the study also concluded that closer short-run control would most likely entail large increases in interest rate volatility, which could seriously inhibit the performance of the economy.

The present study therefore has two main purposes. The first is to describe how the reserve-oriented monetary control procedure works, in theory and in practice.** The second is to assess the effectiveness of the new procedure as it has been implemented. A key feature of any control procedure is how quickly it brings the quantity of money back to a set target when deviations occur. The evidence in this paper for 1981 through the first half of 1982 suggests that the Federal Reserve has continued to follow procedures producing relatively gradual re-entry to the annual target ranges that form the basis of monetary policy. But unlike the earlier study noted above, this study suggests that deviations could be eliminated more rapidly *without* incurring large increases in interest rate volatility.

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**This paper was written in the middle of 1982, prior to the reduction in emphasis by the FOMC on M1 targeting and the major deposit regulation that occurred in the latter part of 1982. Thus, the monetary control procedures described and analyzed are those that prevailed in mid-1982.

For a discussion of the issues raised by using M1 as an intermediate target under interest rate deregulation, see John P. Judd and John L. Scadding, "Financial Change and Monetary Targeting in the United States," available from the authors.

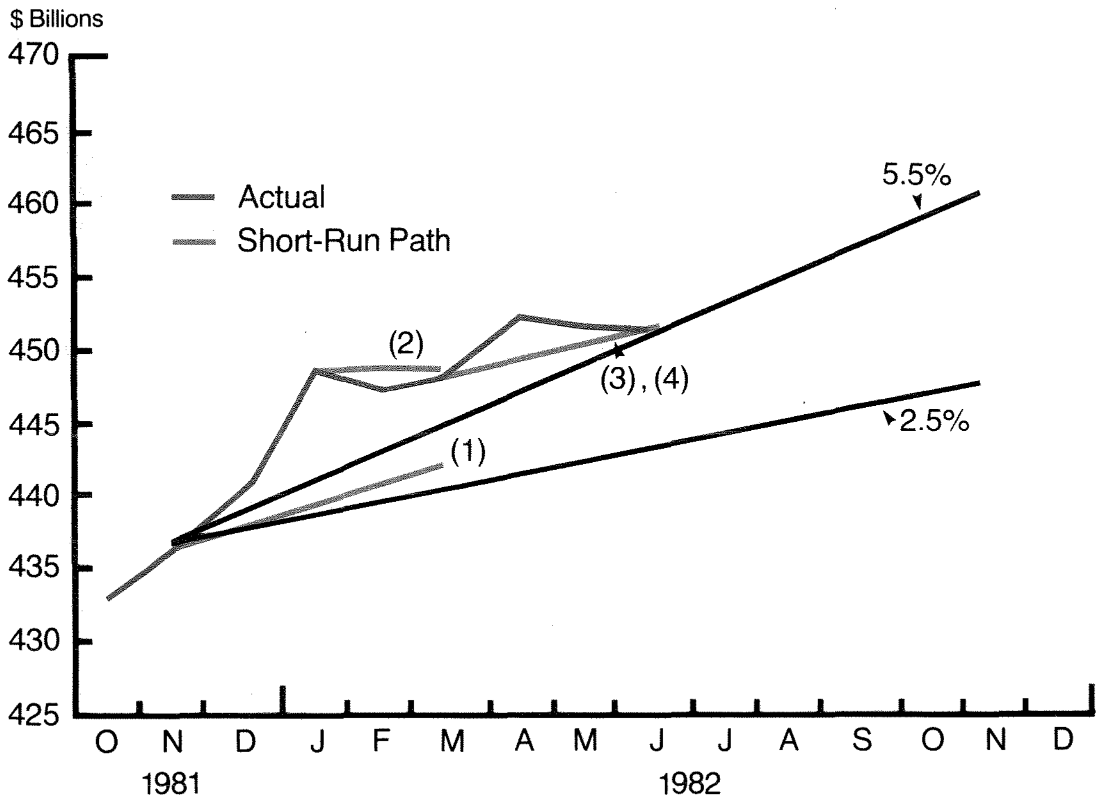
II. Money and Reserve Control Procedures

The Federal Reserve attempts to promote full employment growth at low rates of inflation by maintaining growth rates in certain monetary aggregates that are compatible with its objectives. Each year the Federal Open Market Committee (FOMC) sets *annual growth-rate target ranges* for the monetary (and credit) aggregates. These extend from the fourth quarter of the previous year to the fourth quarter of the current year. In 1982, for example, the range for M1 is 2½ to 5½ percent (see Figure 1).[3] Although ranges are specified for M1, M2, M3 and bank credit, only those for M1 and M2 have had much operational significance since October 1979. These ranges represent the FOMC's goals for average annual money growth. They reflect the long-run policy of gradually lowering the rate of inflation. Over the past three years, the growth rate ranges for M1 have been reduced by about ½ percent each year. The *goal* of this gradualist policy is to reduce growth in money slowly enough over a number of years that inflation is reduced with the smallest possible adverse effects on output and employment.

In recent years, innovations in cash management have made the job of setting appropriate annual growth rates for the aggregates more difficult. These innovations have frequently suggested to policymakers that the public's demand for money is shifting and that growth rate objectives for the aggregates must accommodate these shifts in order to avoid undesired affects on the economy. For example, if the demand for money shifts down and supply is not also lowered, interest rates will fall and monetary policy will have been too expansionary. In 1981, the Fed essentially aimed to keep the quantity of money as measured by M1 near the lower boundary of the target range because the demand for M1 appeared to be shifting downward. By mid-1982, the Fed was content to see M1 at the top of its annual range because of a perceived upward shift in the demand for M1.

Figure 1

Monthly M1—1982



The purpose of this paper is not to evaluate the Federal Reserve's attempts to achieve its macro economic goals, but rather to assess the Fed's procedure for controlling the monetary aggregates in the short-run. Thus, the annual growth rate objectives for M1 are taken as the starting point, without evaluating whether these were the appropriate target ranges for achieving the Fed's macroeconomic goals.

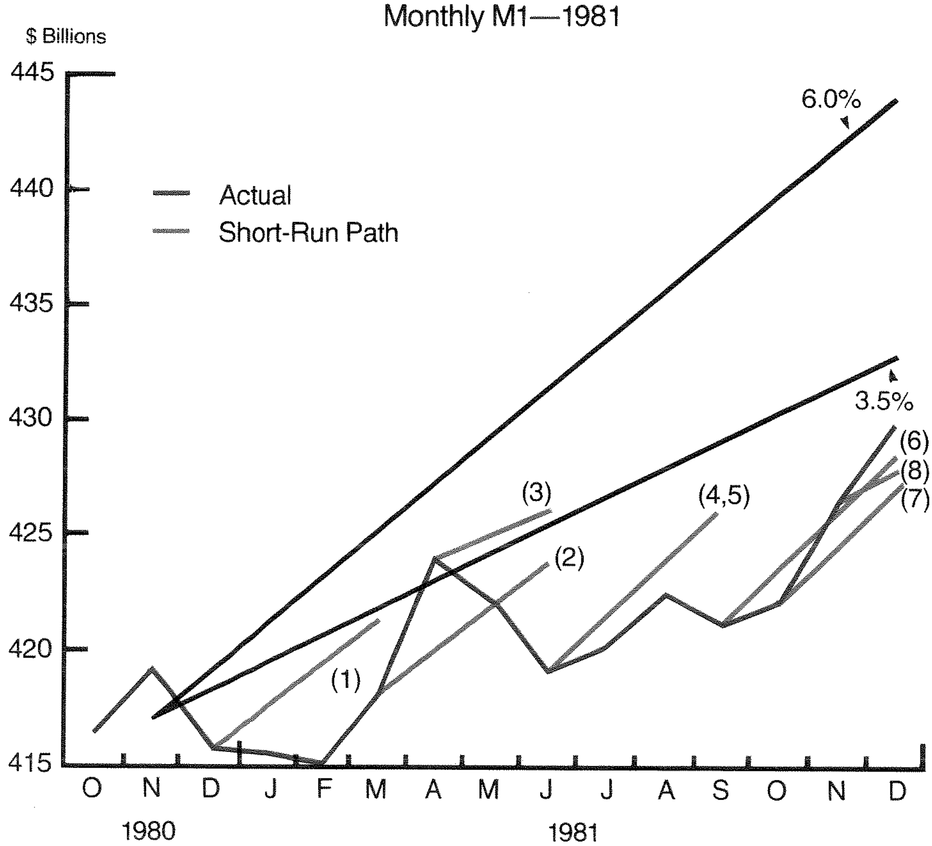
Short-Run Monetary Paths

The Fed's monetary control procedure can be divided into three levels.[4] The first level involves the choice of *short-run paths* for the monetary aggregates (M1 and M2) by the FOMC at each of its meetings. In the final month of each quarter, a three-month path is chosen to cover the next quarter: e.g., on March 31, 1981 a path was chosen for March to June (see line marked (2) in Figure 2). These quarterly paths are sometimes revised in the final two months of the quarter. An example of such a revision occurred on May 18, 1981, when an M1 path for April to June was specified—see the line denoted (3) in Figure 2. This latter path supplanted the original second quarter path.

The short-run paths define the FOMC's preferred rate of re-entry to the longer-run target ranges. For example, again consider the second quarter of 1981. At its March 31 meeting, the Committee chose a growth rate of 5–6 percent for M1, (plotted as 5½ percent in Figure 2 and denoted as (2)) beginning from a March base that was well below the lower boundary of the annual target range. The March path "pointed" M1 back toward its range, and would have achieved the lower boundary of the range within five months (by August) if it had been maintained that long.

Figure 2

Monthly M1—1981



The paths for 1981 and 1982 suggest that the Committee's desired rate of re-entry to the annual range was relatively slow.[5] Each month, the Committee sought to eliminate only a small part of the previous month's deviation of M1 from the annual target range. The shortest re-entry horizon in 1981 was contained in the first quarter path (denoted as (1) in Figure 1), which would have reached the lower boundary of the annual range in early April, about three months after the January deviation just prior to the FOMC meeting in early February. The path denoted 5 would have reached the lower boundary of the annual range in four months, and those denoted 2 and 4 would have reached the lower boundary in 5 months. Finally, paths 6, 7 and 8, chosen for the fourth quarter of 1981 would not have attained the annual lower boundary by the end of that year. Attempted re-entry in the first half of 1982 was somewhat faster. The path denoted 2 in Figure 1 would have achieved the upper boundary of the target range in four months, while the paths denoted as 3 and 4, reach the upper boundary in three and two months, respectively.

The choice of a relatively slow re-entry rate apparently reflects the view that faster re-entry would involve excessive amounts of interest rate volatility. This point was made in the February 1981 Federal Reseve Staff study of the new reserve control procedures. This study concluded that a faster re-entry rate than had been used in 1980 would have provided only marginally closer month-to-month control of M1 at the expense of substantially greater volatility in the Federal funds rate.[6]

Paths for the Reserve Aggregates

The second level of the monetary control procedures translates the short-run paths for M1 and M2 into a path for total reserves over periods between FOMC meetings. These total reserve paths are calculated by multiplying the appropriate reserve requirement ratios by projections of the various reservable liabilities of depository institutions thought to be consistent with the paths for M1 and M2.[7] Since the Fed imposes different reserve requirement ratios on the various components of M1 and M2, and on instruments not in these aggregates, the calculation of the current total reserve paths depends on accurate estimates of movements in the components of M1 and M2 and of other reservable instruments. The Fed must also project reserves held in excess of reserve requirements. These compositional changes require adjustments of the total reserves paths to make them consistent with *unchanged* paths for M1 and M2. These so-called technical, or "multiplier," adjustments are made when necessary on a week-by-week basis. The discussion in the remainder of the paper abstracts from these technical adjustments, and focuses instead on reserve changes designed to be consistent with *changes* in the M1 and M2 paths.

The third level of the control procedure involves the use of a reserves instrument to achieve the short-run paths for M1 and M2. Under certain institutional arrangements, the Federal Reserve has the option of directly manipulating total reserves to control money. However, this approach has not been feasible because of the existing practice of lagged reserve accounting (LRR).[8] This reserve accounting rule requires banks to hold an amount of reserves in any given week based on deposits held two weeks earlier. Banks' required reserves are therefore predetermined in any given week. The Fed, for its part, must supply the banking system with enough reserves to meet the requirement. If the Fed did not do so, it would force some individual banks into a reserve deficiency beyond their control. Thus under LRR, the Fed is not in a position to use total reserves as the money control instrument on a weekly basis.

The Fed's way of dealing with this problem is to use as its control instrument the proportion of total reserves provided to banks through the Federal Reserve discount window. If the Fed wants to pursue a tighter money policy, for example, it supplies fewer reserves outright to the market through open market operations (i.e., fewer non-borrowed reserves). This means that banks will have to acquire a larger proportion of their predetermined required reserves by borrowing at the discount window. Banks, however, are reluctant to go to the discount window because the Fed imposes restrictions on the quantity and frequency of loans it will make to individual banks over specified periods of time.[9] Thus, when the Fed provides fewer non-borrowed reserves, the Federal funds rate must rise relative to the discount rate to induce banks to use up more of their available credit at the discount window. Such increases in the funds rate slow growth in money and total reserves.

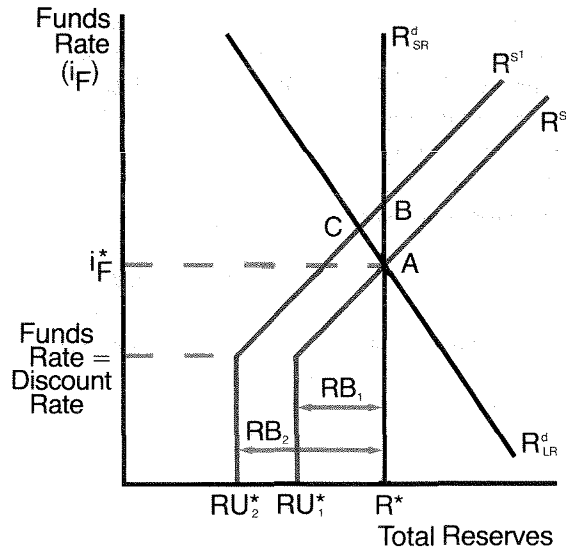
This method of monetary and reserve control is illustrated in Figure 3. Consider first the supply of total reserves, R^S, which consists of two parts. First, so-called nonborrowed reserves (RU) are provided outright to the banking system when the Fed buys open market securities (e.g., Treasury bills) from the public and pays for the securities with bank reserves. Because the Fed directly controls the amount of nonborrowed reserves, this portion of total reserves does not respond to the Federal funds rate, and is depicted by the vertical portion of R^S.

Second, borrowed reserves (RB) are provided when the Fed lends reserves to banks through its discount window. As noted earlier, the quantity of borrowed reserves will rise only if the funds rate increases sufficiently above the discount rate to overcome banks' reluctance to borrow. Thus banks' demand curve of borrowed reserves is upward sloping when the funds rate is above the discount rate. The upward sloping portion of R^S represents the sum of borrowed reserves, which respond positively to the funds rate, plus a fixed amount of nonborrowed reserves. (Note that the kink in R^S occurs where the funds rate equals the discount rate and borrowed reserves are zero. Up to this point, total reserves are composed entirely of nonborrowed reserves, and thus R^S is vertical.)

As noted above, banks' demand for total reserves is predetermined in any given week under LRR. Thus, the short-run demand for reserves, R^D_{SR}, is vertical. However, over periods longer than two weeks, total reserves respond to changes in the quantity of deposits banks issue. Since a higher funds rate restrains deposit growth, the long-run reserves demand, R^D_{LR}, is negatively sloped with respect to the funds rate.

Assume that point A in Figure 3 represents an initial starting point, where total reserves (R*) and the funds rate (i_F*) correspond to the level of M1 on its path. Now, suppose the Fed reduces its desired level for M1. This requires a tighter policy in the reserves market, which means a reduction in nonborrowed reserves from RU_1* to RU_2*. In the short-run, this action raises borrowings (from RB_1 to RB_2) by an equal amount and raises i_F to point B, because the demand for reserves is fixed. However, the higher funds rate restrains money growth contemporaneously, and this leads, with a two-week lag, to slower growth in the demand by banks for total reserves. Thus, over periods longer than two weeks, the demand for reserves responds to the funds rate and so reserves and the funds rate fall from point B to point C.

Figure 3



If the Fed could predict the supply of and demand for money and reserves with certainty, it could always achieve its desired paths (over periods longer than two weeks) by setting nonborrowed reserves at a level such that R^S intersects the long-run reserves demand curve at the desired level of total reserves. Unfortunately, neither R^d nor R^S is known with certainty. For example, unexpected shifts in banks' reluctance to borrow affect R^S. Unexpected changes in the public's demand for M1 and bank credit affect R^d.

Nevertheless, monetary control procedures affect the extent to which the money supply is affected by these and other shocks. For example, lagged reserve accounting allows money to be pushed away from the target path to a greater extent than does contemporaneous accounting. Under LRR, sudden changes in the public's demand for money affect banks' demand for reserves, and thus the funds rate, with a lag of two weeks. Money is therefore, more susceptible to shocks because the interest rate changes needed to moderate deviations of money from target are delayed. Under contemporaneous reserve accounting (CRR) (where current reserve requirements are determined by current deposits), these moderating interest rate changes occur immediately, contributing to tighter monetary control. The Federal Reserve has recently announced its intention to switch to CRR in 1984.

The operating instrument used for monetary control also has an important effect on the susceptibility of money to shocks. In October 1979, the Fed switched from using the Federal funds rate to using nonborrowed reserves as its instrument of control. The funds rate approach had the disadvantage that unanticipated changes in the demand for money and reserves were often accommodated by automatic increases in the supply of reserves as the Fed held its funds rate instrument constant. This accommodation does not occur to the same extent under present procedures, since the Fed often holds nonborrowed reserves constant when unanticipated changes in money and reserves demand occur. With RU fixed, an increase in money and total reserves demand automatically causes borrowed reserves to rise. Greater borrowing at the window causes the funds rate to rise, which tends to retard the increase in money, leading to a smaller monetary control error. Some analysts argue that a total reserves instrument would be even more effective in this regard, but this remains a matter in dispute.[10] The Federal Reserve's switch to CRR will at least give the System the option of using a total reserves instrument, an option not feasible under LRR.

III. Choosing the Nonborrowed Reserve Path

Another important feature of the monetary control procedure, and the focus of this paper, is how quickly the Fed attempts to reenter the longer run target ranges once deviations occur: i.e. how aggressively does the Fed act to offset monetary control errors? The aggressiveness of monetary control actions can be measured by the size of changes in nonborrowed reserves initiated by the Fed in response to deviations of money and total reserves from path. For example, when money overshoots its path, nonborrowed reserves must be lowered in order to raise the funds rate and eventually make money fall back to its path. All else equal, the larger the reduction in nonborrowed reserves, the more rapidly money will go back to path.

The Fed's method of choosing nonborrowed reserves paths involves two basic elements. The first element is the FOMC's choice of a so-called *initial borrowing assumption*. In addition to choosing paths for M1 and M2, which are translated by the staff into a total reserves path, the FOMC also chooses an initial borrowing "assumption" for the intermeeting period. The total reserves path minus the borrowing assumption is the initial nonborrowed reserves path level to be aimed for by the Federal Reserve Bank of New York Trading Desk. Thus when the FOMC chooses paths for M1 and M2 and an initial borrowing assumption it simultaneously chooses a nonborrowed reserves path.

At each meeting the FOMC is presented by the staff with a menu of (usually) three short-run policy alternatives, typically representing possible "tight," "easy" and "status quo" policies. Each alternative contains a combination of paths for M1 and M2, a borrowing assumption, and a Federal funds rate range.[11] The staff designs each path to be internally consistent, that is, the staff projects that a given level of borrowing would be necessary to achieve the corresponding short-run M1 and M2 paths by the end of the period they cover. Thus by construction, the nonborrowed reserves path (which is calculated on the basis of the initial borrowing assumption) is an initial guess at the level of nonborrowed reserves consistent with achieving the short-run monetary aggregates paths. Since the M1 and M2 paths typically reflect an attempt to re-enter the annual target range gradually, so do the nonborrowed reserve paths.

The second element in the Fed's choice of a nonborrowed reserve path involves intermeeting adjustments of the initial nonborrowed path. Since October 1979, the nonborrowed path has sometimes been changed between FOMC meetings in response to projected deviations of total reserves from path. When total reserves have been projected to be deviating from path during control periods by a significant amount, nonborrowed reserves have sometimes been changed in the opposite direction to speed the movement of M1 back to path. Assume, for example, that total reserves are above path. Holding the path for nonborrowed reserves at its original level would limit the total reserves overshoot to consist of borrowed reserves. Higher borrowing would raise the funds rate and help bring M1 and total reserves back to path. The intermeeting adjustments involve raising borrowing and the funds rate even further, by reducing the nonborrowed reserves path from its original level, thereby inducing M1 and total reserves to move back to path more rapidly.

These intermeeting adjustments were used more frequently in 1980 than in 1981 and their size has varied widely among control periods. In 1980, there were six such adjustments ranging in size from around 25 percent of the total reserve deviation to around 125 percent.[12] In 1981, there were two such adjustments, one that was larger than the total reserve deviation, and a second one that was smaller. Fewer intermeeting adjustments were made in 1981, in part because M1 and M2 often gave conflicting signals—M2 was often above its path when M1 was below its path.

There have also been several control periods in 1980-81 when nonborrowed reserves were changed during intermeeting periods in the *same direction* as total reserve deviations. These actions tended to reinforce total reserve deviations rather than offset them. An example is in April of 1980 (during the period of the Special Credit Controls), when nonborrowed reserves came in below their initial paths in an intermeeting period in which total reserves were well below path. This development reinforced the weakness in M1 and total reserves in that period, but cushioned the declines in interest rates that were occurring simultaneously. Two such reinforcing changes occurred in nonborrowed reserves in intermeeting periods in 1980, and three occurred in 1981.[13]

As shown earlier, the FOMC's choice of initial nonborrowed reserves paths represents relatively gradual rates of re-entry to the longer-run target ranges. However, to evaluate the reserve control procedure as a whole, we must also take account of the adjustments to these initial paths made in the intermeeting periods. These latter actions serve as mid-course corrections in response to the latest data. They do not, however, convert gradual re-entry into rapid re-entry. These mid-course corrections were designed to keep on the pre-determined gradual short-run paths. Moreover, the sporadic use of intermeeting adjustments suggests that they have not been a major factor holding M1 to its short-run paths, especially in 1981.

IV. Rates of Re-Entry

The previous section showed that under current operating procedures the Fed sets its nonborrowed reserves path to be consistent with gradual rates of re-entry of M1 and M2 to the annual target ranges. The major argument advanced for gradual re-entry is that it helps stabilize interest rates. Implicit in this argument is the point that attempts to get back to the annual target ranges more quickly would require larger changes in interest rates. These sharp interest rate changes, in turn, can disrupt financial flows and weaken the performance of the economy.[14]

How aggressively should policy attempt to return M1 and M2 to the annual ranges? This is an empirical question the answer to which depends on several factors. The first issue concerns the size of the response in short-term interest rates elicited by the changes in nonborrowed reserves necessary to achieve given rates of re-entry. The remainder of this section examines this factor. Two other factors will be discussed later: The relative benefits provided to the economy by more stable money market interest rates in the short-run versus less persistent deviations of M1 from target, and the nature of deviations, that is, whether or not they are self correcting.

Conceptual Framework

An analysis of how much increase in interest rate volatility will accompany faster re-entry, in part, depends on empirical estimates of the demand and supply relationships in the markets for money and reserves. We have used the San Francisco money market model to estimate the size of changes in short-term interest rates required for various rates of M1 re-entry to the annual target ranges. The model is a monthly structural model which describes the behavior of banks, the nonbank public, and the Federal Reserve in the markets for bank reserves, deposits and bank loans.[15]

The SF model contains a conventional borrowing function in which banks' demand for borrowed reserves depends positively on the funds rates, and negatively on the discount rate, whenever the funds rate is above the discount rate. Thus the model's supply of total reserves schedule looks like the one shown in Figure 3.

In the model, banks' demand for total reserves varies negatively with respect to the Federal funds rate. Since banks' demand for reserves results primarily from reserve requirements, the reserve demand function reflects the response of deposits to the Federal funds rate. The inverse relationship between the funds rate and deposits depends mainly on two relationships. First, arbitrage in financial markets means that rates on longer-term money market instruments, like commercial paper, tend to move up and down with the federal funds rate. The commercial paper rate represents the interest foregone from holding transactions deposits. For this reason, increases in the paper rate induce the public to hold fewer transactions deposits, and banks consequently need supply fewer of these deposits. This is one way in which a higher funds rate reduces M1 and reserves demand. It is the channel of influence common to most money market models.

Second, bank loans act as a catalyst in another channel of influence unique to the SF model. Banks compete to make loans to the public by setting their loan rates relative to rates available in direct finance markets like those for commercial paper and corporate bonds. For any given level of GNP, the public's demand for bank loans depends negatively on the prime rate and positively on the commercial paper rate. Thus, as the prime rate falls relative to the commercial paper rate, banks issue more loans in response to rising demand by the public. Since the proceeds of these loans are generally paid in the form of transactions deposits, increases in M1 and reserves demand are the immediate effect of loan extensions. These newly created deposits tend to stay in the public's portfolio of assets, and thus affect observed M1, for up to six months, according to the empirical estimates.[16]

Changes in the funds rate affect bank loans and M1 through the prime rate. For example, an increase in the funds rate induces a higher prime rate because banks set their prime rates at a variable markup over their cost of obtaining funds to lend. Since the funds rate forms the base of those borrowing costs, the prime rate tends to move up or down with current and lagged funds rates. Thus, if the Federal Reserve takes actions that raise the funds rate, this raises the prime rate. A higher prime rate causes the supply of money to fall by lowering bank loans.[17]

The presence of bank loan effects means that changes in nonborrowed reserves have a larger effect on M1 and a smaller effect on money market interest rates. An increase in RU, for example, reduces the Federal funds rate and raises M1 in two ways. First, the lower funds rate lowers the commercial paper rate, thereby raising the public's underlying demand for money. Second, higher nonborrowed reserves raise M1 via increases in bank loans, as lower funds rates cause the prime lending rate to fall. This added response of M1 to money market interest rates means that given changes in M1 can be accomplished with smaller changes in interest rates. Bank loan effects therefore have an important implication for monetary control—*the costs of short-run control (interest rate volatility) are less than conventional models (without bank loan effects) would suggest.*

Empirical Results

The money market model was used to estimate the changes in the commercial paper rate needed to eliminate given deviations of M1 from target over different periods of time.[18] The analysis applies to M1 deviations that are persistent, in the sense that they would not be eliminated without Federal Reserve action. The estimates are based on simulations of the estimated model. The model simulations included the assumption that the Fed changes nonborrowed reserves by enough to eliminate specified percentages of initial M1 deviations each month. For example, a four-month control horizon involves eliminating 25 percent of an initial M1 deviation each month for four straight months. Constant nominal income and a constant discount rate were two other assumptions. It should be noted that these simulations were not attempts to replicate a sequence of nonborrowed reserves changes that actually occurred under current procedures. Rather they were designed for comparison purposes to indicate the interest rate consequences of *alternative* rates of re-entry to the annual target ranges.

Table 1 shows the model's estimates of the interest rate consequences of alternative rates of re-entry. The numbers shown are the *cumulative* changes in the commercial paper rate (in basis points) corresponding to the various control horizons also shown. For example, the three-month horizon implies that the RU path is designed to eliminate one-third of a $2 billion M1 deviation each month for three months. RU is then set to hold M1 on path for the next three months. The row labeled three months in Table 1 shows that under such a horizon, a $2 billion M1 overshoot would imply that, in the following six months, the commercial paper rate would be 68, 107, 121, 69, 50 and 45 basis points higher *than it would have been* if there had been no change in nonborrowed reserves.

In general, Table 1 suggests that shorter control horizons (i.e., faster re-entry rates), require larger cumulative changes in the commercial paper rate, and that these larger changes must occur sooner. For example, two-month control requires a 152 basis point change in the paper rate by the second month after the M1 deviation, while three-month control requires a 121 basis point increase in the paper rate by the third month. The most extreme variability would occur with one-month control, which requires a 205 basis point change in the paper rate in the first month following the M1 deviation.

The large difference between the one-month and the two-month control rules has to do with the behavior of bank loans. Empirical evidence indicates that the public's loan demand responds to a change in the prime rate with a lag of one month. This presumably occurs because corporate and other types of borrowing are controlled by spending plans which are not revised very much at the same time that borrowing costs change. In any event, the lag in the response of bank loans to Fed policy actions means that a larger interest rate change is required for a given degree of monetary control.

These results suggest that the change in nonborrowed reserves in response to a deviation of M1 from its annual target range could be larger than it is currently without large increases in interest rate volatility. This finding implies that the Fed could attempt to re-enter the range for M1 within 2 to 3 months, rather than the 4 to 5 month horizon often used, without significantly increasing the volatility of the commercial paper rate.

The preceding analysis assumed that income and prices were unaffected by M1 deviations, but removing this assumption only strengthens the case for closer monetary control. This subject is discussed in the next section.

Table 1
Changes in the Commercial Paper Rate Required to Eliminate $2 Billion M1 Deviations Over Various Horizons

Re-entry Horizon	Months Past M1 Deviation					
	1	2	3	4	5	6
One Month	205	99	61	47	42	47
Two Months	103	152	81	54	45	45
Three Months	68	107	121	69	50	45
Four Months	51	76	92	102	62	50
Five Months	41	61	73	82	91	62
Six Months	34	51	63	71	78	86

Assumes the following initial values: M1 = $450 billion and Commercial Paper Rate = 14 percent.

V. Policy Implications and Conclusions

The Federal Reserve's current approach to reserve targeting involves a relatively gradual re-entry to the annual target ranges once a deviation has occurred. According to the empirical evidence presented in this paper the re-entry rate may be shortened at least a few months without causing significantly larger movements in interest rates.

However, this result *by itself* does not necessarily justify a shortening in the control horizon. The advisability of such a decision depends upon the sources of disturbances to the money and reserve markets that cause the money control errors, and an assessment of the relative costs of interest rate volatility relative to the costs of money control errors.

An argument cautioning against a strong reaction to deviations of total reserves from path is that many deviations are self-correcting. To illustrate, the error term from an estimated money demand equation is relatively large and may account for a large number of temporary M1 and, therefore, total reserves deviations. These deviations correct themselves in a short time without Fed actions that would cause interest rates to change. However, since it is often very difficult to distinguish temporary from permanent disturbances, strong Fed reactions could sometimes unnecessarily induce interest rate volatility.

Nevertheless, by seeking to avoid the error of reacting when it is unnecessary, the Fed runs the risk of not reacting appropriately when disturbances are persistent. It is the latter error that permits M1 deviations to persist long enough to have an undesired effect on GNP and prices. Thus, even if temporary disturbances occurred more frequently than persistent disturbances, it might be worthwhile to choose a faster re-entry rate. In other words, a larger number of unnecessary reactions might be less costly to the economy than a smaller number of large persistent monetary control errors.

Permanent disturbances to the market for money often require very large persistent changes in interest rates to bring M1 back to target. For example, assume that a sudden surge in bank loans causes M1 to accelerate above its targeted path. If this deviation were not corrected quickly enough, GNP would also begin to accelerate. Ultimately, interest rates would have to increase to offset *both* the surge in loans *and* GNP. If the Fed had taken corrective action early, it would only have had to offset the surge in loans. This narrower task requires a smaller and less persistent increase in short-term interest rates.

A problem with persistent swings in short-term interest rates is that they are likely to show up in long-term rates. Investors can choose between buying a long-term security with a maturity equal to their desired investment period, or a series of short-term securities with maturities that add up to the investment period. If the Fed were to offset an M1 control error gradually in an investment period, short-term interest rates would rise gradually in that same period. Investors anticipating the rise, would then prefer to buy short-term securities in series, re-investing each time at the expected higher short-term rates. They would adopt this strategy unless the yield on the long-term security also rose. On the other hand, they would not need this inducement to buy the long-term security if they expected the M1 control error to be offset quickly by a short, sharp increase in short-term interest rates. In this way, gradual re-entry to the M1 paths means more persistent movements in short-term interest rates, which in turn means that longer-term interest rates are affected to a greater degree by monetary control actions. These long-term interest rates are of potentially great importance because they affect business investment and housing.

Finally, deviations of M1 from target can also induce volatility in long-term rates if the deviations are perceived by the public to be persistent enough to affect inflation. A great deal of empirical evidence links higher inflation with faster growth rates for money. Thus, when the public sees a persistent increase in money growth, it may anticipate more inflation. Long-term interest rates then rise because they include a premium for inflation. This relationship between money growth and long-term rates is especially likely to exist when the Treasury runs large budget deficits and when Federal Reserve credibility is low. Faster rates of re-entry to the M1 target can be a more emphatic way of showing that M1 deviations will not persist long enough to affect inflation.

In summary, a more aggressive approach to short-run monetary control most likely would reduce the incidence of persistent M1 deviations that have significant effects on GNP and prices. Such an approach would also reduce the risk that the Fed would be forced to induce persistent swings in short-term interest rates to eliminate large money deviations. Finally, a more aggressive approach might contribute to the stability of long-term interest rates, which are especially important for the performance of the economy.

FOOTNOTES

1. **New Monetary Control Procedures**, Federal Reserve Staff Study—Volumes I and II, Board of Governors of the Federal Reserve System, February 1981.

2. Stephen Axilrod, "Overview of Findings and Evaluation," **New Monetary Control Procedures**, Volume I, pp. A6 and A23.

3. M1 is the sum of currency, traveler's checks, demand deposits, and other checkable deposits. M2 is M1 plus overnight RPs and eurodollars, non-institutional money market funds, and savings and small time deposits. In 1982, M2 was redefined to include retail RPs and to exclude institutional money market funds. M3 is M2 plus large time deposits, term RPs, and institutional money market funds.

4. See E. J. Stevens, "The New Procedure," **Economic Review**, Federal Reserve Bank of Cleveland, Summer 1981, pp. 1–17, for a detailed discussion of the reserve control procedures.

5. In February 1980–November 1980 M1 paths were chosen such that on average, the FOMC sought to eliminate **29.2 percent** of the previous month's error in each current month. Peter A. Tinsley, Peter von zur Muehlen, Warren Trepeta, and Gerhard Fries, "Money Market Impacts of Alternative Operating Procedures," **New Monetary Control Procedures**, Volume II, and Axilrod, February 1981, pp. B1–B4.

6. See Axilrod (1981), p. A17, and Tinsley, von zur Muehlen, Trepeta and Fries (1981).

7. Fred Levin and Paul Meek, "Implementing the New Procedures: The View from the Trading Desk," **New Monetary Control Procedures**, Volume II, pp. A1–A5.

8. See Warren L. Coats. "Lagged Reserve Accounting and the Money Supply Process," **"Journal of Money, Credit and Banking**, May 1976, VIII (1) pp. 167–180: Daniel E. Laufenberg, "Contemporaneous Versus Lagged Reserve Accounting," **Journal of Money, Credit and Banking**, May 1976, VII(1), pp. 239–246.

9. See Murray E. Polakoff and William L. Silber, "Reluctance of Member Bank Borrowing: Additional Evidence," **Journal of Finance**, March 1967, pp. 88–92.

10. David Lindsey, *et. al.*, "Monetary Control Experience Under the New Operating Procedure," **New Monetary Control Procedures**, Federal Reserve Staff Study-Volume 2.

11. The funds rate range has had little operational significance, except occasionally to trigger Committee consultation when the funds rate violates the range.

12. The following equations show how to calculate the difference between the actual value taken on by nonborrowed reserves in a given control period and the initial nonborrowed reserves path implicitly chosen by the FOMC.

(1) $R = RU + RB$

(2) $R^* = RU^* + RB^*$

(3) $RU^* - \overline{RU}^* = + \overline{RB}^* - RB^* + R^* - \bar{R}^*$

where

R = total reserves

RU = nonborrowed reserves

RB = borrowed reserves

* indicates current path

"Bar" * indicates initial path chosen by FOMC.

By subtracting (2) from (1), we obtain

(4) $R - R^* = RU - RU^* + RB - RB^*$.

Next we solve (3) for RB^*, and substitute it into (4), to obtain

$RU - \overline{RU}^* = (R - R^*) - (RB - \overline{RB}^*)$.

Thus, the difference between RU and the FOMC's *initial* path for RU equals the total reserve deviation minus the deviation between borrowed reserves and the FOMC's initial borrowing assumption.

An indication of these values can be obtained from data and description in "Monetary Policy and Open Market Operations in 1980," and "Monetary Policy and Open Market Operations in 1981," **Quarterly Review**, Federal Reserve Bank of New York, Summer 1981 and Summer 1982, respectively.

13. This occurred in the control periods ending 2/6/80, 4/23/80, 2/4/81, 4/1/81, and 12/23/81.

14. Axilrod (1981), p. A17.

15. See John P. Judd and John L. Scadding, "Liability Management, Bank Loans, and Deposit 'Market' Disequilibrium," **Economic Review**, Federal Reserve Bank of San Francisco, Summer, 1981 and "What Do Money Market Models Tell Us About How to Implement Monetary Policy?–Reply," **Journal of Money, Credit and Banking**, November 1982, Part 2, pp. 868–876. Also see Richard G. Anderson and Robert H. Rasche, "What Do Money Market Models Tell Us About How to Conduct Monetary Policy," **Journal of Money, Credit and Banking**, November 1982, Part 2, pp. 796–828.

16. Changes in bank loans have a significant and persistent impact on the monetary aggregates because money is a buffer stock in the public's portfolio. Money acts much like an inventory of goods in a warehouse. Such an inventory, by its very nature, will represent the residual of a whole set of other decisions which, in the short-run could keep the "inventory" from its desired level. The view of money demand as largely passive in the short-run, accommodating

itself to changes in the supply of money, reflects the transactions costs of closely managing money balances. Unanticipated inflows or outflows of funds cause inventories of money balances in the short run to wander away from their desired levels because it is too costly for some money holders to monitor closely their accounts, and to make the necessary purchases and sales of securities frequently enough to bring money balances quickly back to their desired levels.

This view does not dispute the importance of the emergence in the 1970's of sophisticated cash management techniques and new instruments like repurchase agreements. These developments mean that transactions costs are now so low for *some* money holders, especially large corporations, that they hold only money balances that are consistent with their underlying demands. However, smaller and less sophisticated corporations and households could easily hold more or less transactions balances than they desire for an extended period of time. Most households and small corporations have relatively low money balances on average, and actions to adjust those balances to desired levels may be costly relative to the benefits of holding exactly the desired amount of money. If money, therefore, finds its way into these "loosely" managed portfolios, it may stay there for awhile. Moreover, actions of one money-holder to bring balances into line may throw other holders out of balance. For this reason, the system as a whole takes longer to adjust than does any one household or corporation.

Whether these effects are significant enough to make a difference is a factual question. Recent empirical estimates at this bank suggest that buffer stock effects are significant —that the monetary aggregates can depart significantly from levels desired by the public for up to six months at a time; that is, an *increase* in bank loans causes the *level* of money to depart from the public's underlying demand for about six months.

17. The commercial paper rate affects bank loans with a positive sign. This rate also rises with the funds rate. This means that theory cannot tell whether bank loans vary positively or negatively with the funds rate. However, the empirical results in the San Francisco model show an inverse relationship.

18. See Judd and Scadding, 1982 for empirical estimates of the key equations used in the simulations. Other equations in the model can be obtained from the authors.

Dynamic Adjustment in the Demand for Money: Tests of Alternative Hypotheses

John P. Judd and John L. Scadding*

Alternative theories of the public's demand to hold money are among the most widely tested theories in macroeconomics because the demand for money occupies a central role in monetary policy. The Federal Reserve conducts monetary policy by attempting to achieve target growth rates for several measures of money, with a large amount of attention traditionally focused on M1, which represents the public's holdings of currency plus checkable deposits. If the Fed wants to lower inflation, for example, it reduces the growth rate of M1. But it can do so only by inducing the public to *want* to hold fewer M1 balances. The conventional explanation of how this happens, in the short-run, is that the Fed raises interest rates on financial instruments that are substitutes for M1. Since alternative investments now have a higher yield, the public chooses to hold more of them and less money. This process affects prices and output of goods and services because the public's demand for these goods and services varies negatively with interest rates. That is, increases in these rates represent higher borrowing costs to finance spending. By raising these borrowing costs, efforts to slow M1 growth tend to lower output and the growth of prices.

Both theory and evidence point to interest rates (which measure the opportunity cost of holding money), and either income or wealth as the major determinants of the demand for money. The quantity of real money balances determined by these variables defines the long-run equilibrium, or "desired," quantity of money demanded. It is generally recognized, however, that in the short run the quantity of money actually held by the public can differ from this long-run, or desired level. The reason for this is that it is too costly to rearrange portfolios constantly to keep desired and actual real money balances the same at every point in time. Any discussion of money demand in the short run must, therefore, specify the relationship between actual money balances and the desired level. This is typically done by specifying a dynamic adjustment process by which actual money balances and the desired level are made equal.

The conventional assumption is that this process of dynamic adjustment consists of the public adjusting the quantity of money it holds gradually over time, until it is equal to the long-run demand for it. This version of dynamic adjustment has become almost universally accepted, despite the lack of much research comparing it to alternative formulations. As we shall see, the conventional formulation is a reasonable description of dynamic adjustment when the supply of money passively accommodates itself to changes in the demand for money. It seems less well suited to situations in which the supply of money can change independently of money demand —in other words, to a world in which there can be *exogenous* changes in the supply of money.

This line of criticism is not new, but it has been largely ignored until recently. It began to receive renewed attention when evidence emerged after 1973 that the conventional equation was going badly off track in predicting money.[1] The large cumulative overpredictions of M1 from 1974 through mid-1976 were explained as a so-called "shift" in the demand for money associated with rapid innovation in the financial markets that al-

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lowed the public to economize on its holdings of money balances.

This episode of financial innovation also coincided with the period in which the Federal Reserve paid increasing attention to targeting the monetary aggregates; i.e., to a strategy that was consistent with providing a greater element of exogeneity in the money supply. As a result, several alternative dynamic formulations of short-run money demand were proposed and tested—formulations which it was argued were more consistent with a world in which changes in the *supply* of money were an important independent source of changes in the observed quantity of money held by the public.

Unfortunately, it is practically impossible to compare the performance of the different formulations in the existing literature because they were not designed to explain the same variable[2]. Some used money as the dependent variable in their regressions, some used prices and others used interest rates. Another reason making comparisons difficult is that the different regressions were not estimated over the same sample period. The purpose of this paper is to find the best specification of short-run money demand dynamics. Our method is to survey the different past formulations and to provide estimates of them that are comparable. To this end we show how the ostensibly different formulations are actually specific cases of a general formulation for predicting the level of real money balances. We use this result to investigate how successful each is in "explaining" the same variable—the level of real money balances—over the same sample period, 1959/Q1 to 1974/Q2. We also investigate how successful the variants are in predicting the post-1974/Q2 period, the period in which the conventional specification went seriously off track.

Finding the correct specification of short-run dynamics is an important task for two reasons. First, an incorrect specification of short-run dynamics will most likely affect estimates of the elasticities of the determinants of long-run money demand, estimates that are important for predicting the impact of money on output and prices. This consideration is particularly important in view of the prolonged shifts in conventional money demand equations since 1973, and the problems these shifts cause for monetary policy.

Second, the form taken by short-run dynamics has an important implication for the cost of close short-run monetary control. As shown below, the conventional specification implies that a small exogenous change in money by the Federal Reserve requires a large change in interest rates. Since the Fed historically has considered interest rate volatility an important cost of short-run monetary control, reliance on the conventional specification tends to discourage precise short-run control. The alternative specifications of money demand dynamics, which are designed to be more consistent with an exogenous money supply, imply that the increase in interest rate volatility resulting from efforts to control money more closely in the short run would be smaller than typically thought.

The empirical results in this paper do not support the conventional specification of short-run dynamics, in which observed money accommodates itself gradually to changes in money demand. Uniformly superior results were obtained from equations in which money demand adjusts (through changes in the price level) in response to independent changes in the supply of money. Moreover, the latter equations showed significantly less instability during 1974-76 than the conventional dynamic specification. Specifically, the dynamic forecast error of the best alternative equation was over 65 percent lower than that of the conventional equation by the end of this period.

I. The Conventional Specification

Most quarterly money demand specifications allow for temporary differences between the observed stock of real (price deflated) money balances in the short run, and the public's desired level of such balances in the long run. Typically, a partial adjustment model is used, in which the market for money is assumed to adjust over time to restore long-run equilibrium after it is disturbed by shocks. This general specification raises the need to identify the specific exogenous and endogenous variables in the market for money. The variables causing shocks define the exogenous variables, while the variables which adjust to these shocks constitute the endogenous variables.

The traditional specification, as derived by Gregory Chow, implicitly assumes that the money supply is endogenous, adjusting to exogenous changes in income and interest rates operating through the demand for money.[3] This specification assumes that the quantity of money changes in the current quarter by some fraction of the difference between this quarter's long-run demand and last quarter's actual level. Money will continue to adjust over time until the actual level equals the long-run demand. This specification is shown in equation (1),

$$\Delta m_t = \lambda[m_t^d(i,y) - m_{t-1}], \qquad (1)$$

where Δ denotes a change in a variable, m is *real* (price-deflated) money balances, m^d is desired or equilibrium money balances, shown as a function of its arguments—interest rates (i) and real income (y)—and λ is a parameter that measures the speed with which real balances adjust to the desired level.

The conventional specification can be re-arranged slightly to yield an alternative interpretation, shown in equation (2),

$$\Delta m_t = \lambda(m_{t-1}^d - m_{t-1}) + \lambda \Delta m_t^d(\Delta i, \Delta y) \qquad (2)$$

where Δm_t^d denotes the change in money demand, here shown as a function of changes in interest rates (i) and real income (y). Hence the Chow specification implicitly views the quantity of real money balances as adjusting to two factors. The first is a fraction (λ) of the difference between desired and actual money balances from last period (the first term of equation (2)). The second is the current period "shock" caused by changes in money demand originating in exogenous changes in interest and income (the latter term of (2)).

This interpretation is consistent with the standard description of individual money demand in the presence of portfolio adjustment costs. Individuals take income and interest rates as exogenous determinants of their demand for money, but because portfolio adjustment is costly, changes in these variables do not induce immediate adjustment to the new desired level of money.

Conventional Specification Problems

The Chow specification (or a close variant) has become the almost universally accepted version of the short-run demand function for money. In large part, its popularity is due to an influential article by Stephen Goldfeld, written in 1973, that demonstrated its remarkable stability over most of the postwar period up to then.[4] This popularity has not gone unchallenged, however, as a few authors have argued that this specification was not necessarily a suitable specification of the dynamics of the *market* for money, whatever its merits might be as a description of individual behavior.[5] In particular, these authors have argued that the Chow specification implies some rather peculiar dynamics of money market adjustment when the supply curve of money shifts (say, because of a change in monetary policy). Thus, the unanswered question is whether this specification is appropriate for situations in which shocks occur in the *quantity* of money, rather than in the arguments of money demand. Presumably it is this last specification that is relevant when there are exogenous changes in the supply of money.[6]

There are two potential defenses of the conventional dynamic specification. The first is that equation (1) is a structural equation that is agnostic about which variable is endogenous. Thus, if the money supply were exogenous and money demand endogenous, equation (1) simply could be rearranged to solve for whichever argument of money demand takes the burden of adjustment. In most large-scale macroeconomic models, for example, the money demand function is typically used to solve for the short-term rate of interest, which is viewed as the endogenous variable that adjusts to clear the market for money in the short-run whenever the money supply is taken as exogenous.

The problem with this defense is that the conventional specification assumes that it takes a large change in interest rates to induce a small change in money in the short-run. This result follows from the partial adjustment of money to exogenous changes in interest rates. When the equation is turned around so that it predicts interest rates as a function of exogenous money, it suggests that interest rates have to overshoot their long-run levels in the short-run in order to induce the public to accept a change in the stock of money supplied by the Fed.[7]

This result seems inconsistent with the rationale for partial adjustment in the short run—namely, that the costs of adjusting portfolios make it suboptimal to adjust fully. By this reasoning, when an individual experiences an unexpected cash receipt, he presumably does not attempt immediately to return his cash holdings to their desired long-run value. Instead, the costs of adjusting his portfolio cause him to dispose of the excess cash gradually over time.[8]

The same will be true in the aggregate. When there is an exogenous increase in the supply of money, the pressure on interest rates to change will be relatively little in the short run as the public will tend to hold on to the increase initially. Hence adjustment costs do not point to the overshoot pattern of interest rates implied by the conventional specification. Moreover, the actual behavior of interest rates does not appear to conform to the overshoot pattern either. Simulations of the Treasury bill rate using the money demand function in the Board's FMP (Federal Reserve-MIT-University of Pennsylvania) model showed "spikes" that were not present in the actual data.[9] Since the FMP money demand function has a conventional partial adjustment specification, these spikes can be presumed to be the product of the overshoot built into that specification.

The second defense of the conventional partial adjustment model argues that the stock of money was effectively determined by demand under the Federal Reserve's pre-October 6, 1979 procedure of using the federal funds rate to try to control money. This procedure consisted of pegging short-term interest rates, or at least moving them only very gradually, in response to deviations of money from target.[10] In order to do that, it is argued, the Federal Reserve had to provide whatever quantity of money the public demanded. Hence the quantity of money was determined by the demand for money. In such a world, the conventional specification of money market adjustment—which has the quantity of money adjusting to changes in the demand for it—seems appropriate.

The major theoretical assault on this position is found in the work of Brunner and Meltzer who argue that it fails to distinguish between money and credit.[11] In a world in which there are distinct markets for bonds (credit), as well as for money and commodities, it is possible to have exogenous changes in the supply of money even when the monetary authority pegs interest rates. Suppose, for example, that firms decide to spend more on plant and equipment. They may finance this desired increase in spending by floating new bonds. Hence the increased demand for commodities (investment goods) is matched by an increased supply of bonds (demand for credit). The increased demand for credit puts pressure on interest rates to rise. To prevent this, the monetary authority increases bank reserves, allowing the banking system to purchase the new bonds through the creation of new deposits (i.e., an increase in money supply). The firms' demand for money has not increased except transiently: they have borrowed the money to spend, not to hold.

At this point, there is an increase in the supply of money that is not matched by any increase in the demand for money. The change in money supply, therefore, is exogenous in the sense used in this paper. The firms borrowing the money will spend it. The recipients of that expenditure will find themselves with excess money balances, which they in turn will get rid of by spending more. Output and prices will expand in the process until the rise in the aggregate demand for money matches the increase in money supply. Thus, even with interest rate pegging by the monetary authorities, it is possible for changes in the supply of money to cause changes in the demand for money, rather than the other way around.

The conventional specification of money demand is inadequate for describing this situation because its dynamics model a case in which money is entirely endogenous. The purpose of the alternative specifications described in the next section of this paper is to provide a partial adjustment mechanism consistent with money supply exogeneity.

II. Alternative Specifications

The alternative formulations of short-run money demand are summarized in Table 1. This table lists, for each specification, the variable that adjusts to changes in the exogenous variables, as well as the exogenous, or shock, variables themselves—i.e., the variables whose changes make observed money deviate from the public's long-run demand for money. The various specifications can be grouped into two major categories. The first category consists of variants of the conventional specification, which view the quantity of money as adjusting with a lag to changes in the demand for money. In contrast, the members of the second group—the exogenous money specifications—view the demand for money as adjusting with a lag to changes in the supply of money.

Supply-adjusting equations

The conventional versions begin with the Chow specification (1.A.1), whose properties we explored extensively in the preceding section. Its use

Table 1
Conventional and Alternative Specifications of Dynamic Adjustment of Money Demand (all variables in logarithms)

	Adjusting Variables	Shock Variables	Specification of Adjustment Equations
A. Conventional			
1.A.1 Chow (1966) (Goldfeld 1973)	Money/Prices	Income, interest rates	$\Delta m_t = \lambda[m^d_t - m_{t-1}]$
1.A.2 Goldfeld (1976)	Money	Income, interest rates, prices	$\Delta M_t = \lambda[M^d_t - M_{t-1}]$
1.A.3 White (1978)	Money	Income, prices	$\Delta M_t = \Delta m^d_{(i),t} + \lambda[(M^d_t - \Delta m^d_{(i),t}) - M_{t-1}]$
1.A.4 Judd-Scadding (1982b)	Money	Income, interest rates, prices, bank loans	$\Delta M_t = \delta\Delta BL_t + \lambda[M^d_t - \delta\Delta BL_t - M_{t-1}]$
B. Alternative			
1.B.1 Starleaf (1970)	Income, interest rates	Money, prices	$\Delta m^d_t = \lambda[m_t - m^d_{t-1}]$
1.B.2 Artis-Lewis (1976) (Laidler 1980)	Interest rates	Money, income, prices	$\Delta i_t = \lambda[\frac{m_t - m_{(y),t}}{a_1} - i_{t-1}]$
1.B.3 Jonson (1976)	Prices	Money, income, interest rates	$\Delta P_t = \lambda[M_t - m^d_t - P_{t-1}]$
1.B.4 Coats (1982)	Unanticipated prices	Money, income, interest rates	$\Delta P_t - (\Delta P)^e_t = \lambda[M_t - m^d_t - (P_{t-1} + (\Delta P)^e_t)]$
1.B.5 Carr-Darby (1981) (Laidler 1980)	Prices	Unanticipated money, permanent income, interest rates	$\Delta P_t = (\Delta M)^e_t + \lambda[M_t - m^d_t - (P_{t-1} + (\Delta M)^e_t)]$

Notes:

(a) M^d_t (long-run demand for nominal money balances) $= m^d_t + P_t$

(b) m^d_t (long-run demand for real money balances) $= a_o + a_1 i_t + a_2 i_{s,t} + a_3 y_t$, where i is a short-term market rate of interest, i_s is a rate on savings or time deposits, and y is real income.

(c) ΔBL_t = change in bank loans

(d) $m_{(y),t}$ = demand for money exclusive of that determined by the market rate of interest: $= m^d_t - a_1 i_t$

(e) $\Delta m_{(i),t}$ = change in demand for money caused by change in market interest rate

(f) $(\Delta P)^e_t$ = anticipated inflation

(g) $(\Delta M)^e_t$ = anticipated money growth of money divided by prices as the dependent variable implies that the quantity of money adjusts fully within a quarter to changes in the price level. But the equation also assumes that there is only partial adjustment to changes in interest rates and real income. This first feature seems implausible, and has led others to propose 1.A.2, which makes the quantity of nominal money adjust with a lag to changes in interest rates, income *and prices*.[12] A third variant, proposed by William H. White, specifies that money adjusts without any lag to changes in money demand that are caused by changes in interest rates (i.e., interest rates are not a shock variable), but retains the lag in response to changes in real income and prices (1.A.3).

Table 1 lists the Judd-Scadding formulation of money demand as the last of the conventional specifications (1.A.4). Its inclusion in this category is somewhat problematic. Like the conventional specifications, it views the quantity of money as adjusting with a lag to changes in money demand. In this regard, it looks very similar to the Goldfeld formulation (1.A.2). However, the Judd-Scadding equation also recognizes that changes in the observed quantity of money can result from exogenous changes in the supply of money.

The equation is part of a monthly money market model, which incorporates the Brunner-Meltzer point that changes in the demand for bank loans cause exogenous shifts in the supply function of money. As was outlined in Section I, costs of adjusting portfolios cause the public to hold these exogenous changes in money in the short run, rather than to try to get rid of them. The Judd-Scadding specification recognizes this point by adding to the public's observed holdings of money balances the exogenous changes in money caused by the growth of bank loans. Thus, observed money adjusts with a lag both to changes in demand factors (income, interest rates and prices) and a supply factor (changes in bank loans). The authors have previously found that these bank loan effects are statistically and economically significant in monthly data from 1976 through mid-1982.[13]

Demand-adjusting equations

The second class of short-run money functions—variants 1.B.1 through 1.B.5—consists of partial adjustment specifications in which the demand for money adjusts with a lag to changes in the quantity of money. With one exception, all of these variants have one of the arguments of money demand—either the interest rate, income, or prices—as the adjusting variable. The adjustment of money demand then is implicitly specified in terms of the adjustment of this variable. For example, in the Artis-Lewis formulation (1.B.2), interest rates are assumed to adjust to clear the market for money. Thus the specification is in terms of the partial adjustment of interest rates to, among other things, the quantity of money. However, since money demand is a function of the interest rate, this specification can be rewritten in terms of the adjustment of money demand to the quantity of money.

In the same way, the Coats, Jonson and Carr-Darby formulations assume that prices adjust to clear the market for money. Again implicit in these formulations is the idea that the demand for money is adjusting since the (nominal) demand for money depends, among other things, on prices. The one exception to having only one variable clear the market is Starleaf's formulation, in which the adjustment is specified explicitly in terms of money demand, with no assumption made whether it is interest rates, income or some combination of the two that adjusts to clear the market for money.

The three price-adjusting variants differ from each other in whether or not they distinguish between actual and expected inflation, and between actual and anticipated money growth. The Jonson formulation is the simplest, with actual prices adjusting with a lag to changes in actual money. The Coats formulation, on the other hand, distinguishes between actual and expected prices. Prices adjust fully on a contemporaneous basis to expected changes in prices $(\Delta P)^e$. However, growth in money that is inconsistent with the expected change in prices creates a deviation between money and the long-run demand for it that is ultimately removed by the adjustment of actual inflation to the rate of growth of money. Thus in the Coats formulation prices adjust with a lag not to the actual change in money but only to the excess of money growth over the expected rate of inflation.

Similarly, the Carr-Darby formulation assumes that prices adjust completely without any lag to anticipated changes in money. Partial adjustment occurs only with respect to unanticipated changes in money. This distinction is consistent with a rational expectations viewpoint, and presumably can be justified by arguing that the costs of adjusting portfolios to anticipated changes are much smaller because they can be planned for in advance.

III. The Canonical Form

Although the different formulations vary in their assumptions about which variable adjusts to clear the market for money, they can all be expressed according to a general rule: i.e., they have the same canonical form. All of the formulations are descriptions of how long-run equilibrium in the market for money is disturbed by changes in certain variables in the short run, and how long-run equilibrium is ultimately restored. To illustrate, consider the Chow specification (equation 1.A.1, Table 1). It has the quantity of real money balances adjusting with a lag to changes in the (long-run) demand for money. This formulation can be rewritten as

$$m_t - m_t^d = (1-\lambda)(m_{t-1} - m_{t-1}^d) - (1-\lambda)\Delta m_t^d(\Delta i, \Delta y). \qquad (3)$$

This equation shows that the extent to which money deviates today from the long-run demand for it is a function of two things. First is the amount of last period's deviation that is carried over to today. Since λ is the speed with which actual money adjusts to the demand for it, $(1-\lambda)$ of last period's deviation remains after taking into account yesterday's adjustment. The second contribution consists of the exogenous disturbances to money demand in the current period, caused by changes in its arguments—interest rates and income. Again, since a contemporaneous adjustment of λ is made to these disturbances, the residual deviation that remains is $(1-\lambda)$ of these disturbances.

Letting $\widetilde{m}_t = m_t - m_t^d$ be money disequilibrium, (3) can be written as,

$$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} - (1-\lambda)\Delta m_t^d \qquad (4)$$

which describes the dynamic process by which long-run equilbrium is restored, and identifies the source of disequilibrium, in this case, changes in money demand.

All the other formulations shown in Table 1 can be put in the same canonical form. The Jonson formulation, for example, in which prices rather

Table 2
Canonical Form of Conventional and Alternative Specification of Dynamic Adjustment in Market for Money (all variables in logarithms)

A. Conventional	
2.A.1 Chow	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} - (1-\lambda)\Delta m_t^d$
2.A.2 Goldfeld	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} - (1-\lambda)\Delta P_t - (1-\lambda)\Delta m_t^d$
2.A.3 White	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} - (1-\lambda)\Delta P_t - (1-\lambda)\Delta m_{(y),t}^d$ */
2.A.4 Judd-Scadding	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\delta\Delta BL_t - (1-\lambda)\Delta P_t - (1-\lambda)\Delta m_t^d$
B. Alternative	
2.B.1 Starleaf	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\Delta M_t - (1-\lambda)\Delta P_t$
2.B.2 Artis-Lewis	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\Delta M_t - (1-\lambda)\Delta P_t - (1-\lambda)\Delta m_{(y),t}^d$ */
2.B.3 Jonson	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\Delta M_t - (1-\lambda)\Delta m_t^d$
2.B.4 Coats	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\Delta M_t - (1-\lambda)(\Delta P)_t^e - (1-\lambda)\Delta m_t^d$
2.B.5 Carr-Darby	$\Delta\widetilde{m}_t = -\lambda\widetilde{m}_{t-1} + (1-\lambda)\Delta M_t^{**/} - (1-\lambda)\Delta m_t^d$

Notes:
* Includes change in money demand caused by changes in passbook savings rate as well as by changes in income.
** Unanticipated money growth only.
$\widetilde{m}_t = m_t - m_t^d$

than money do the adjusting, can be written as

$$\Delta \tilde{m}_t = -\lambda \tilde{m}_{t-1} + (1-\lambda)\Delta M_t - (1-\lambda)\Delta m_t^d. \qquad (5)$$

Thus, the Jonson formulation adds changes in nominal money to the list of exogenous variables that disturb long-run equilibrium. In the conventional formulation, on the other hand, it does not appear because it is one of the variables assumed to adjust to remove disequilibrium. Table 2 lists the canonical version for all of the variants described in Table 1.

Estimation

This canonical form is also used to organize the estimation results shown in Table 3, where the estimated adjustment parameter (λ) is reported along with the impact elasticities for the exogenous disturbance variables. These impact elasticities are $(1-\lambda)$ times the respective long-run elasticities. For changes in money and prices, the long-run elasticities are constrained to be unity. The others—income and interest rate elasticities—are left free to be estimated by the data.

All of the equations were estimated with real money balances as the dependent variable. Long-run demand, m^d, was expressed in terms of its basic arguments—interest rates and income—and these arguments were used as explanatory variables. Two interest rates were used: a short-term market rate, in this case the four- to six-month commercial paper rate, and the rate on passbook savings accounts. Real GNP was used as the income variable in all equations except the Carr-Darby specification, which uses permanent income. The expected inflation rate series used to estimate the Coats equation was an updated series on the permanent or underlying inflation rate reported by Scadding (1979). The unanticipated money series used in the Carr-Darby equation consisted of the regression residuals from fitting a time series model to changes in money.[14] The definition of money used throughout was M1, and the estimation period is 1959/Q 1-1974/Q 2.

The Cochrane-Orcutt procedure was used for the equations that could be estimated using ordinary least squares. Some of the equations, however, had

Table 3
Estimates of Canonical Form of Dynamic Adjustment of Money Demand
1959:1-1974:2

Specification	Adjustment Parameter	Impact Elasticities: Income	Impact Elasticities: Commercial Paper Rate	Impact Elasticities: Savings Dep. Rate	Impact Elasticities: Prices	Impact Elasticities: Money	Standard Error	Serial Corr. Coefficients
A. Conventional								
3.A.1 Chow	0.220	−0.440	0.072	0.095	—	—	0.0045	0.408
	(7.57)	(3.12)	(4.45)	(1.41)				(3.46)
3.A.2 Goldfeld	0.203	−0.501	0.064	0.078	−0.797	—	0.0041	0.428
	(8.87)	(3.78)	(4.05)	(1.13)	(8.87)			(3.67)
3.A.3 White	0.193	1.652	0.400	−3.499	−0.807	—	0.1339	—
	(1.40)	(2.95)	(21.15)	(21.15)	(1.40)			
3.A.4 Judd-Scadding	0.249	−0.411	0.048	0.056	−0.751	.096*	0.0041	0.473
	(8.11)	(4.03)	(3.74)	(1.06)	(8.11)	(1.51)		(4.15)
B. Alternative								
3.B.1 Starleaf	0.982	—	—	0.017	−0.018	0.018	0.0061	0.983
	(105.40)			(0.62)	(105.4)	(105.4)		(41.42)
3.B.2 Artis-Lewis	−64.93	−9.334	—	0.742	−63.93	63.93	0.0056	0.989
	(0.33)	(21.70)		(0.03)	(0.33)	(0.33)		(50.50)
3.B.3 Jonson	0.076	−0.235	0.085	0.109	—	0.924	0.0027	0.032
	(20.90)	(0.94)	(3.88)	(0.95)		(20.90)		(0.24)
3.B.4 Coats	0.085	−0.464	0.072	0.164	—	0.914**	0.0022	0.162
	(20.36)	(2.14)	(3.67)	(1.85)		(20.03)		(1.25)
3.B.5 Carr-Darby	0.028	−1.120***	0.514	0.335	—	0.972****	0.0034	0.167
	(10.40)	(0.85)	(4.90)	(0.74)		(10.40)		(1.29)

t ratios reported in parentheses are for coefficients in estimated real balance equations; standard errors and serial correlation coefficients are from same regressions.
* exogenous component due to bank loan growth only.
** growth in money minus expected growth in prices
*** elasticity with respect to permanent income
**** unanticipated money growth only

to be estimated by nonlinear least squares (adjusted for first-order serial correlation) because of nonlinear constraints on the parameters. Estimates did not converge when an attempt was made to allow for serial correlation in the White variant (3.A.3). For this equation, the estimates without any adjustment for serial correlation are reported.

Estimation results

The estimation results are presented in Table 3. A comparison of the standard errors of the estimates of the equations provides a clear ordering of success. Two of the worst performances are turned in by equations 3.B.1 and 3.B.2, in which income and/or interest rates adjust to restore equilibrium. These equations produce standard errors of .0062 and .0056—over double the standard errors of the best in the other groups. These errors translate into annualized errors of 2.5 and 2.2 percentage points, respectively. Furthermore, equation 3.B.2 yields a negative estimate of the adjustment parameter that is greater than 1, implying that the dynamic process is unstable.

The conventional specifications, equations 3.A.1-3.A.4, have significantly smaller standard errors than those of the preceding group, with the exception of the White formulation. The Judd-Scadding and Goldfeld equations 3.A.4 and 3.A.2 show annualized standard errors of 1.6 percentage points, while Chow (3.A.1) shows 1.8 percentage points. All three equations yield quite similar parameter estimates. For example, they indicate that 20 to 25 percent of last quarter's disequilibrium is restored each quarter. In addition, they all indicate that the interest elasticity of money demand is relatively small, ranging from 0.19 to 0.32 in the long run. The White formulation, on the other hand, gives a mediocre performance. Its standard error is the worst of any equation by a wide margin, and it shows implausibly high income and interest rate elasticities that also have the wrong sign.

The best performance as a class is turned in by the price adjusting equations. The Coats, Carr-Darby and Jonson specifications have standard errors that are 35 to 45 percent lower than the conventional group. A further advantage of these specifications is that no significant autocorrelation appears in the residuals, whereas the conventional specifications all have statistically significant autocorrelation. Since evidence of autocorrelated residuals may indicate misspecification, and since it is argued by some that the dynamics of the conventional form *are* misspecified, this is a potentially damaging result for the conventional specification.

The major problem with both the Jonson and Carr-Darby equations is that real income enters with statistically insignificant coefficients, although the sign on this variable conforms to theory. In the Coats equation, the implied long-run income elasticity is significant, and its value of 0.51 is comparable to the estimates in the conventional models. These results suggest that the Coats specification, in which unanticipated prices adjust to changes in money, interest and income, yields the best performance of any equation tested over the sample period.

Only 7 to 8 percent of disequilibrium is eliminated each quarter in the Jonson and Coats equations, while the Carr-Darby equation has even slower adjustment of 3 percent. This compares to adjustment of about 20 percent in the Goldfeld equation. However, this difference can be explained by which variable does the adjusting. In the

Table 4
Dynamic Simulations of Real Money Balances
Out-of-Sample: 1974/Q3-1980/Q4

Specification	Root Mean Squared Error	Mean Error	Error in: 1977/Q1	Error in: 1980/Q1
A. Conventional				
4.A.1 Chow	.097	−.091	−.100	−.131
4.A.2 Goldfeld	.096	−.088	−.105	−.127
4.A.4 Judd-Scadding	.090	−.083	−.098	−.118
B. Alternative				
4.B.3 Jonson	.065	−.060	−.069	−.099
4.B.4 Coats	.054	−.048	−.036	−.079
4.B.5 Carr-Darby	.065	−.059	−.046	−.089

Goldfeld specification, money adjusts (relatively quickly) to prices and other variables, whereas in the Jonson, Coats and Carr-Darby equations, prices adjust relatively slowly to money and other variables.

Simulation Results

Table 4 contains the results of dynamic simulations over 1974/Q3-1980/Q3 of the equations in Table 3 that yielded reasonable estimation results. The White, Artis-Lewis, and Starleaf equations were excluded because they did not meet this criterion.

The simulation results suggest an ordering of performance similar to that of the estimation results: *the price-adjusting models outperform the conventional specifications*. Specifically, the root-mean-squared-error (RMSE) over 1974/Q3–1980/Q3 from Coats' equation translates into an annualized error of 22 percentage points, with a mean error (ME) of −19 percentage points (actual minus predicted). The standard Goldfeld equation has a RMSE of 38 percentage points and a ME of −35 percentage points.

The large negative mean errors of all the formulations reflect the well-known shift in the demand for money in 1975–76. Clearly, *all* equations tested show such a shift. However, the shift evidenced by the price adjusting formulations is smaller than for the conventional ones. In 1977/Q1, the quarter in which the large cumulative shifts in all four equations end, the Coats, Carr-Darby and Jonson equations are off track by from 3.6 to 6.0 percent while the conventional equations are off by about 10 percent. Finally, the simulation of the Coats formulation uniformly outperforms all other equations.

IV. Conclusions

The empirical results in this paper suggest several conclusions. First, money demand equations in which prices adjust to exogenous changes in money, interest and income outperform equations in which money is the adjusting variable. Equations in which money is the adjusting variable, in turn, outperform equations where interest rates and income are the adjusting variables. Second, the Goldfeld specification, which has been used almost exclusively in the literature, in which money is the adjusting variable, was *not* found to be the equation most consistent with the quarterly data during the period 1959–80. The uniformly superior specification was that of Coats, in which unanticipated prices adjust to exogenous changes in money, interest rates and income. Third, no specification tested was free of the cumulative shift in the demand for money in 1974/Q3–1976/Q4. However, equations in which prices are specified as the adjusting variable significantly reduced the size of overpredictions of M1 produced by dynamic simulations. The Coats specification was especially successful in this regard, producing a simulation error which by 1977/Q1 was 66 percent smaller than the error from the Goldfeld equation.

Two more points are of interest. The first concerns interest rate volatility and monetary policy. Our results indicate that it is inappropriate to use a conventional Goldfeld equation, which assumes a dynamic process fitting a world with an endogenous money supply, to draw inferences about the interest rate volatility that would result from close short-run monetary control. Put somewhat differently, it is inappropriate to solve a Goldfeld equation for the rate of interest, and then forecast the interest rate on the basis of changes in an exogenous money supply. This procedure, which is commonly followed in large econometric models, often suggests that a small change in money growth rates would produce wild interest rate swings in the short-run. This conclusion is not reliable because it is based on a misspecified process of dynamic adjustment in the money demand function. A specification of that process depends critically on which variables are made exogenous and which endogenous. Thus, if the assignment of exogenous and endogenous variables were changed (say, for a hypothetical policy simulation), the specification of dynamic adjustment would also need to be changed for the results of the simulation to be reliable.

Second, the finding that the best performance was turned in by money demand equations with prices adjusting to exogenous changes in money *and* interest rates seems consistent with the point made by Brunner and Meltzer discussed earlier. Their point is that changes in money supply can occur independently of changes in money demand even if the Fed pegs interest rates. This can occur, for example, when the demand for credit rises as corporations finance spending on new plant and equipment. The increased credit demand, which can be independent of money demand, applies pressure on interest rates. In order to peg the interest rates, the Fed would increase bank reserves and the money supply. Thus the supply of money *and* the rate of interest can both be exogenous to the demand for money.

FOOTNOTES

1. See Judd and Scadding (1982a).

2. Laidler (1980) has compared the empirical properties of some, but not all of these formulations. Also see Laidler (1980) and White (1981) for a discussion of theoretical issues raised by alternative dynamic specifications.

3. See Chow (1966).

4. See Goldfeld (1973).

5. See, for example, Tucker (1966), Starleaf (1970) and Darby (1972).

6. It is possible to give equation (2) an interpretation in which changes in (nominal) money are exogenous. This is done by noting that the left-hand variable is the change in real balances, and that this change is simply the difference between nominal money growth and the rate of inflation. Hence it can be argued that it is the rate of inflation that is adjusting to money market disequilibrium, caused, among other things, by changes in money growth. Rearranging (2) to reflect this interpretation yields

$$\Delta P_t = \Delta M_t - \lambda(m^d_{t-1} - m_{t-1}) - \lambda \Delta m^d_t(\Delta i, \Delta y),$$

in which the growth in money appears as one of the right-hand exogenous variables. The difficulty with this interpretation, as several writers have noted, is that it implies full contemporaneous adjustment of inflation to changes in money growth.

7. See Tucker (1966).

8. This view seems entirely consistent with inventory-theoretic money demand functions of Baumol (1952) and Miller and Orr (1966 and 1968).

9. See Modigliani, Rasche and Cooper (1972).

10. See Judd and Scadding (1979).

11. See Brunner and Meltzer (1976).

12. See Goldfeld (1976) and White (1978).

13. See Judd and Scadding (1981 and 1982b).

14. The following equation was used

$$\Delta \ln M1_t = \underset{(3.41)}{2.20} + \underset{(4.37)}{.48}\Delta \ln M1_{t-1} + \underset{(0.96)}{.11}\Delta \ln M1_{t-2} - \underset{(0.71)}{.08}U_{t-1}$$

$\bar{R}^2 = .21$ $\quad$ DW = 1.92 $\quad$ SEE = 2.88

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